Remarks on the relation between physics and faith

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Abstract

It is a quite common view among people, that are not aware of the developments in modern physics, that it is part of human nature to substitute religious faith in places where there is no knowledge. Therefore, an increase in knowledge would lead to a decrease in the necessity of faith. Further, it is argued that, ideally speaking, a full knowledge of the laws of nature would make obsolete any sort of religious faith and would ultimately allow a complete control of nature by man. Since referring to nature, such views must be founded in the natural sciences of which physics is the most fundamental. Therefore, the question whether such views are compatible with the

current state of natural sciences is ultimately decided in physics. Indeed, it is likely that these simplistic views have their origin in the world view generated by the successes of Newtonian physics from the middle of the 17th century until the beginning of the 20th century which viewed the physical world as a type of mechanical clock in which the motion of the gears affect each other in a precise and predictable way. In particular, the paper points out that the above views are no longer supported by current physics and that abstracted world views cannot be considered as part of natural sciences, but only as belief systems.

1 Introduction

It is a quite common view among people, that are not aware of the developments in modern physics, that it is part of human nature to substitute religious faith in places where there is no knowledge. Therefore, an increase in knowledge would lead to a decrease in the necessity of faith. A classical example is the medieval belief that the sun, moon, and stars were moved in their orbits by souls ('anima'), who had to carry on this work until the last day. This belief was made obsolete by Kepler's laws of planetary motion. Further, it is argued that, ideally speaking, a full knowledge of the laws of nature would make obsolete any sort of religious faith and would ultimately allow a complete control of nature by man.

Since referring to nature, such views must be founded in the natural sciences of which physics is the most fundamental. Therefore, the question whether such views are compatible with the current state of natural sciences is ultimately decided in physics. Indeed, it is likely that the above simplistic views have their origin in the classical world view generated by the successes of Newtonian physics from the middle of the 17th century until the beginning of the 20th century which viewed the physical world as a type of mechanical clock in which the motion of the gears affect each other in a precise and predictable way. It was assumed that with some more effort all the connections between those gears would soon be found. It is

generally accepted that most physicists in the 19th century believed that all the fundamental laws of nature were already known. In this world view there is no space for a Christian God or religious faith.

The paper points out that the above views are no longer supported by current physics and that abstracted world views cannot be considered as part of natural sciences, but only as belief systems. For this, it sketches the medieval world view as the starting point of the development of physics in the 17th century, describes and analyzes that development and states cornerstones of Newtonian physics which have been assumed evident, but nevertheless have been destroyed by the Theory of Special Relativity, the Theory of General Relativity, Quantum Mechanics, Quantum Electrodynamics and the Standard Model of Particle Physics.

2 The medieval world view

At the beginning of the development of modern physics in the 17th century by Johannes Kepler, Galileo Galilei and Issac Newton, the medieval world picture derived from the Ptolemaic universe prevailed in Europe [22].

It consisted of a series of 10 concentric transparent spheres or 'heavens' with the earth at their center. Fixed to the first 7 innermost spheres were the 'planets', i.e., the moon, Mercury, Venus, the Sun, Mars, Jupiter and Saturn. Fixed to the 8th sphere [1] were the stars. The 9th sphere was called the 'First Movable' [2] that carries no luminous body and therefore is invisible. Finally, the 10th sphere is 'the very Heaven' [3] and full of the God, whose is considered immaterial and unaffected by time. Hence God is unmovable, but the love for Him puts the the 'First Movable' into rotation from east to west and transfers its to the other spheres. The lower spheres are rotating more slowly from west to east and are forced back by the daily

[1] The 'Stellatum'.
[2] The 'Primum Mobile'.
[3] The 'Caelum ipsum'.

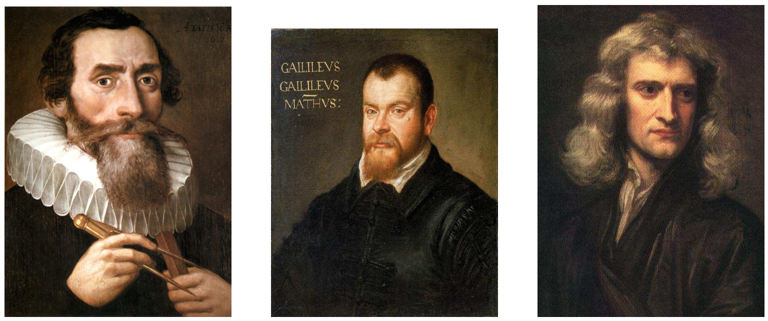

Fig. 1: Portraits of Kepler (1610), Galilei (ca. 1605-07) and Newton (1689).

impulse of the ‘First Movable’. All spheres are inhabited by ‘intelligences’. The terrestrial domain of the universe inside the first innermost sphere contains bodies made out of the elements fire, air, water and earth. The heavenly bodies above the moon are made of a more perfect fifth element, the ‘Quintessence’ or ‘aether’.

3 The development of physics in the 17th century

3.1 Description of the development

In the following, we have a brief look at some of the scientific achievements of Kepler, Galilei, Newton and their influences on the philosophic and religious views in the last half of the 17th century.

Kepler $(1571 - 1630)$ was a devout Christian. One of Kepler’s favorite biblical passages is

- John 1:14 (KJV)

“And the Word was made flesh, and dwelt among us, (and

> we beheld his glory, the glory as of the only begotten of the Father,) full of grace and truth."

For him, this indicates that the divine archetypes were made visible as geometric forms in nature. In particular, a sphere was a reflection of Christian Trinity with God the Father as its center, Christ the Son as periphery and the intervening space as Holy Spirit. He tried to explain the distances among the six Copernican planets [1] by circumscribing and inscribing each orbit with one of the five regular polyhedrons.[2] In a letter from 1605, he views the universe no longer as a divinely animated being, but as a clockwork [18]

> "Scopus meus hic est, ut Caelestem machinam dicam non esse instar divinj animalis, sed instar horologij ($\cdot$ qui horologium credit esse animatum, is gloriam artificis tribuit operj $\cdot$), ..."

One of Kepler's main scientific achievements are his three laws of planetary motion $(1609 - 1618)$. They are as follows:

1. All planets move around the Sun in *elliptical* orbits, with the Sun in one of the foci.

2. A radius vector joining a planet with the Sun sweeps out equal areas in equal lengths of time.

3. The square of the time required by a planet to complete one orbit is directly proportional to the cube of its mean distance from the Sun.

Galilei $(1564 - 1642)$ can be considered as the father of experimental sciences by performing precise measurements on mechanical systems with a subsequent mathematical analysis of the results. In particular, he studied balls rolling on inclined planes. From the results, he concluded that bodies

[1] Mercury, Venus, Mars, Saturn, Jupiter and Uranus.
[2] The pyramid, cube, octahedron, dodecahedron, and icosahedron.

do not need a proximate cause to stay in motion which contradicts the Aristotelian view that any motion presupposes a mover. This result led, after generalization by Rene Descartes $(1596 - 1650)$ to motion on a straight line, to Newton's law of inertia. Timing the rate of the descent of balls, he deduced that freely falling bodies [1] would be uniformly accelerated at a rate independent of their mass. Moreover, he understood that the motion of any projectile was the result of simultaneous and independent motion in the horizontal direction and falling motion in the vertical direction. In 1638, Galilei wrote [14],

> "It has been observed that missiles and projectiles describe a curved path of some sort; however no one has pointed out the fact that this path is a parabola. But this and other facts, not few in number or less worth knowing, I have succeeded in proving; ..."

Finally, in the 'Assayer' from 1623, Galilei insisted that 'the book of the Universe' is written in the language of mathematics [13]

> "Philosophy is written in this grand book, the universe, which stands continually open to our gaze. But the book cannot be understood unless one first learns to comprehend the language and read the letters in which it is composed. It is written in the language of mathematics, and its characters are triangles, circles and other geometric figures without which it is humanly impossible to understand a single word of it; without these, one wanders about in a dark labyrinth."

Influenced by the results of Kepler, Galilei and later Newton, the dominant philosophy of the last half of the 17th century was that of Rene Descartes. Mechanics is the basis of his physiology and medicine. *Descartes* believed

[1] in particular, not subject to the resistance of air

Fig. 2: Portrait of Leibniz, date unknown.

that all material bodies, including the human body, are machines that operate by mechanical principles. It is known that Newton studied the works of Descartes and other *mechanical philosophers*, who *viewed physical reality as composed entirely of particles of matter in motion and* who *held that all the phenomena of nature result from their mechanical interaction*.

In 1684, *Newton* $(1643 - 1727)$ published his famous three laws of motion which provide the basis of mechanics to this day [23]. Together with his and independently Gottfried Wilhelm Leibniz's $(1646 - 1716)$ discovery of differential and integral calculus, these laws transformed the field of mechanics into an exact science. In 1687, Newton formulated his law of gravitation that have Kepler's laws of planetary motion and the results of Galilei's experiments on motion on inclined planes as particular consequences. Hence the laws of mechanics also unified the knowledge on mechanical systems at that time.

After the groundbreaking work of Newton, the motion of the planets and comets of the solar system was predictable to high accuracy and understood on the basis of natural laws. The announcement by Le Verrier in 1859, that there was an unexplained advance in the perihelion of Mercury, was not regarded as a failure of Newtonian Mechanics, but due to unknown gravitational sources. An explanation for this advance was given by Einstein's Theory of General Relativity in 1916 [11]. A first indication for the breakdown of classical physics appeared at the end of 19th century in form of the failure of the Rayleigh-Jeans law to describe the observed behaviour of

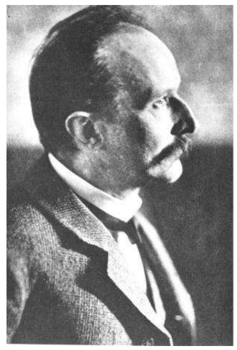

Fig. 3: Max Planck (1910).

black body radiation. In 1900, Max Planck [1] derived his radiation law that gave a correct description, but a the cost of assuming that the oscillators comprising the blackbody could absorb energy only in discrete amounts, in quanta of energy. This led to the development of Quantum Mechanics.

Because of its highly accurate descriptions, mechanics became regarded as the ultimate explanatory science. Phenomena of any kind, it was believed, could and should be explained in terms of mechanical concepts. Newtonian physics was used to support the deistic view, in particular represented by Voltaire $(1694-1778)$*, that God had created the world as a perfect machine that then required no further interference from Him, the Newtonian world machine or Clockwork Universe.*

The confidence in the validity of these ideas is best described by the following statement [21] of Laplace $(1749-1827)$ in 1814:

> "We ought then to regard the present state of the universe as the effect of its anterior state and as the cause of the one which is to follow. Given for one instant an intelligence which could comprehend all the forces by which nature is animated and the respective situation of the beings who compose it – an in-

[1] In 1918, Nobel prize winner in physics "in recognition of the services he rendered to the advancement of Physics by his discovery of energy quanta".

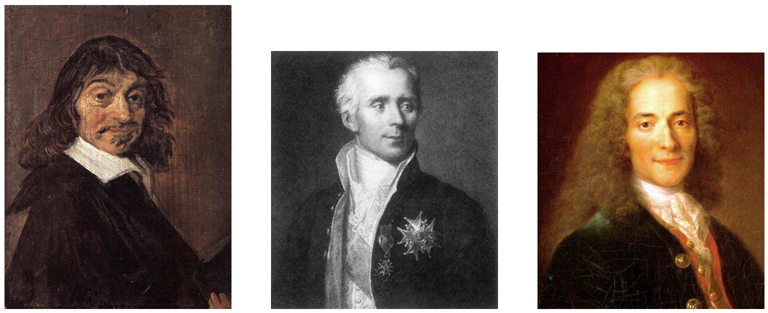

Fig. 4: From left to right: Portraits of Descartes (1649), Laplace and Voltaire (1718).

> telligence sufficiently vast to submit these data to analysis – it would embrace in the same formula the movements of the greatest bodies of the universe and those of the lightest atom; for it, nothing would be uncertain and the future, as the past, would be present to its eyes."

In the aftermath, the method of Newtonian Mechanics was applied successfully to a growing number of areas of nature. The marvelous development of mechanics in the 18th century, thermal engineering and thermodynamics in the beginning of the 19th century give evidence of the power of that approach.

3.2 Analysis of the development

In the following, from a modern perspective, we analyze the important changes in the approach to nature that have occurred in 17th century.

3.2.1 The method of natural sciences

First, the method of natural sciences had been established. This method tries to separate nature into systems that are to a good approximation 'isolated', in the sense that the inclusion of their interaction with the remaining

part of nature would introduce only small changes below the intended accuracy of description. Note that such separation is non-trivial and involves an *assumption* that itself cannot be verified. Such supposedly isolated systems are studied by precise experiments or observations. The corresponding measurements are subjected to a mathematical analysis with the goal of abstraction of a Natural Law or 'Theory'. Predictions of the theory are tested by additional experiments or observations. If the results are consistent with those predictions within the accuracy of the measurements, the theory is maintained. Otherwise, the theory is revised. In the last case, the process is continued until consistency with known experiments and observations is reached.

Note that even if the initial assumption of isolation of the system is false, this process can still lead to an accurate description by the theory if, for some reason, it successfully 'captures' the influence of the surrounding. The simplest way to achieve this is to include a larger number of constants into the theory that can be adapted to measurements. To avoid the last, it is generally demanded that a theory should be in some sense 'simple' or 'aesthetic'.

Experiments and observations provide the basis of the method of natural sciences in that their outcome decides on the 'truth' of a theory. If predicted qualitatively and quantitatively correctly by a theory, a natural phenomenon is considered to be 'understood' or 'explained' *in terms of the theory*.

Note that in the case of a false assumption of isolation of the system, a 'true' theory is still 'false' in the sense that it cannot be expected that it describes correctly the 'nature' of the system. Note also that *there are no proofs in natural sciences*, although Galilei uses this notion in the above cited passage from 1638.[1] Differently to mathematics, those are based on experiment, not on logic. Ultimately, in natural sciences even logic is subject to experimental verification.

[1] This is not in conflict with the fact that theoretical physics describes physical systems by mathematical means. In this way, physical problems are mapped onto mathematical problems. Inevitably, the last need to be solved by pure mathematical methods, i.e., by theorems and proofs.

3.2.2 Successes and abstracted world views

The focus on mechanical phenomena allowed the development of a highly successful theory, i.e., Newtonian Mechanics, that was believed to be consistent with experiments and observations of increasing accuracy until the beginning of the 20th century.[1] Under the impression of the successes of this theory, there was abstracted a philosophical world view, the Clockwork Universe where God is regarded as a creator of natural laws governing its evolution and the agent that set the clock initially into motion. After that, the evolution of the world is thought to be completely deterministic. It is believed that a miracle, in the sense of a divine intervention into nature which does contradict natural laws, does not occur.

3.2.3 Abstraction of world views from natural sciences

That abstraction of a philosophical world view, although tempting, provides a classic example of the quite common *mistake* of the layman *to identify a theory with the part of nature it only describes*. The method of natural sciences *defines* the 'truth' of a theory as its consistency with known experiments and observations within the accuracy of measurements. There is no generally accepted method available to decide whether the theory is true in some absolute sense. On the contrary, the history of physics showed that ultimately every theory turned out to be 'false', in the sense that its predictions were inconsistent with more precise experiments or observations which made its revision necessary. Such revisions led to new theories which explained the phenomena of the older theories qualitatively and quantitatively and at the same a large number of additional natural phenomena those older theories could not account for. *But, as will be pointed out later on, in every step in this sequence, concepts that were fundamental in the formulation of the older theory were negated by its successor. From this*

[1] The announcement by Le Verrier in 1859 that there was an unexplained advance in the perihelion of Mercury was not regarded as a failure of Newtonian Mechanics, but due to unknown gravitational sources.

point of view, it can very well be said that fundamental aspects of the older theories were false. There is no reason to believe that this will be different for future theories. Here, it should also be taken into account that by the rules of logic, a false statement can imply a true statement. For instance, a compound statement falsely claiming a true statement and a false statement at the same time leads to a true statement by omitting that false part of the statement. The statement

> *'Tigers are mammals and mice are reptiles'*

is false, but it implies the true statement

> *'Tigers are mammals'*.

Hence, a false theory can very well lead to results consistent with experiments or observations. For these reasons, the abstraction of philosophical a world view from such theories is inherently flawed.

Therefore, the abstraction of philosophical world views from natural sciences leads to a belief system, only. In particular, differently from these sciences, such views cannot claim exactness.

In addition, from a Christian point of view, it appears that the creation of a philosophic world view, *by abstraction from natural sciences or by theological reasoning from statements in the bible*, violates commandments in the bible:

- Exodus 20 (KJV)

  > "4 Thou shalt not make unto thee any graven image, or any likeness of any thing that is in heaven above, or that is in the earth beneath, or that is in the water under the earth. 5 Thou shalt not bow down thyself to them, nor serve them: ..."

- or in Deuteronomy 5 (KJV)

  > "8 Thou shalt not make thee any graven image, or any likeness of any thing that is in heaven above, or that is in the earth beneath, or that is in the waters beneath the earth: 9 Thou shalt not bow down thyself unto them, nor serve them: ..."

3.3 A general remark on Darwin's theory of evolution

Since I am no biologist, I will make only some very general remarks on the relation between physics and the natural sciences of biology and chemistry. These start from definitions of these fields given in the Encyclopedia Britannica [2]:

> "Biology is the study of living things and their vital processes."

A large part of those processes have been recognized as chemical processes which led to the creation and growing importance of the subfields of Biochemistry and Molecular Biology. Judging from the successes of those, it does not seem to be too far fetched to say that biology will ultimately turn out to be (at least in principle) a subdivision of chemistry.

> [Chemistry is] "the science that deals with the properties, composition, and structure of substances (elements and compounds), the reactions and transformations they undergo, and the energy released or absorbed during those processes."

The laws that govern those properties of substances have been recognized as the laws of quantum mechanics. Hence, it can be said that chemistry is (at least in principle) a subdivision of physics.

As a consequence, physics increasingly emerges as the root of the natural sciences. Therefore, there is reason to view Darwin's and other theories of evolution from a physicist's point of view. Presently, because of their ad hoc nature and lack of quantitative statements, from this point of view, those theories seem to be more working hypotheses than theories. Also for this reason, they seem to be unsuitable for the abstraction of a world view.

4 The descent of the mechanical theory of nature

In the following, we state the established physical theories subsequent to Newtonian Mechanics in chronological order and give a short description of fundamental changes they introduced.

4.1 Maxwell's Theory of the electromagnetic field

That descent of the mechanical theory of nature started with the analysis of electrical and magnetic phenomena in the 19th century, in particular with the discovery of radio waves propagating at the speed of light in vacuum.[1] Such waves were predicted by the electromagnetic theory of James Clerk Maxwell $(1831-1879)$ from 1873 [25]. They were produced and measured in the laboratory by Heinrich Hertz $(1857-1894)$ in 1887.

It is worth noting that in attempting to illustrate Faraday's law of induction [2], Maxwell constructed a mechanical model [25]. Also, it was assumed that those waves had some sort of a material carrier, the so called 'ether', similar to sound waves that are compression waves in matter. In 1881 and 1887, this theory was shattered by the Michelson-Morley experiments, which were designed specifically to detect the motion of the Earth through the ether

[1] i.e., at the speed of $299,792,458$ meters per second

[2] that a changing magnetic field gives rise to an induced electric field

 

Fig. 5: From left to right: Maxwell and Hertz, dates unknown.

and which indicated that there was no such effect.

As a consequence, the existence of non-mechanical entities in addition to matter was realized, i.e., force fields that are propagating through empty space.

4.2 The Special Theory of Relativity

Maxwell's electromagnetic equations require waves to move at the speed of light in vacuum in every inertial system, that is in every reference frame where free [1] matter moves with constant speeds and on a straight lines. Two such reference frames move relative to each other at a constant speed. Therefore, the propagation of electromagnetic waves contradicts common experience [2] that suggests that the wave speed should appear to be different as measured from different inertial systems.

In 1905, Albert Einstein $(1879-1955)$ [3] made the constancy of the speed of light and the requirement that the laws of physics should assume the same form in every inertial system *postulates* of his Special Theory of Relativity

[1] i.e., free from the action of external forces
[2] of motion that is small compared to the speed of light in vacuum
[3] In 1921, Nobel prize winner in physics "for his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect".

Fig. 6: Albert Einstein, ca. 1905.

[9]. This led to radical changes of Newtonian Mechanics. The concept of absolute time or rather of absolute simultaneity of events lost its meaning and became dependent on the reference frame instead. As a consequence, also the concept of rigid bodies had to be abandoned. *All these notions are central in Newtonian Mechanics*.

4.3 The Theory of General Relativity

Newton's law of gravitation is incompatible with the Theory of Special Relativity and therefore needed a revision after the arrival of this theory. This was achieved in 1915 by Albert Einstein's Theory of General Relativity [10, 11] that absorbs the gravitational field into the geometry of space-time. In this, the theory generalizes the Special Theory of Relativity and again radically alters Newtonian Mechanics on a fundamental level. In particular, it removes the gravitational field from any energy momentum balance of a physical system under the influence of such a 'field'. As a consequence, in general there is no conserved total energy or momentum associated to such a system.

Fig. 7: From left to right: Heisenberg (ca. 1924), Born and Jordan.

4.4 Quantum Mechanics

The Theory of Quantum Mechanics or more general Quantum Theory was developed by Werner Heisenberg $(1901-1976)$ [1], Max Born $(1882-1970)$ [2] and Pascual Jordan $(1902-1980)$ in 1925 because of the clear failure of Newtonian Mechanics to describe the physical phenomena in the range of atomic distances, i.e, 10^{-10} meter $= 0.1$ nanometer and below [16, 1, 3]. This theory shook the foundations of physics like no other before or after because of its probabilistic character. That character allows statements on individual systems only in the exceptional cases of the occurrence of probabilities of value 1.

It denies the possibility of a deterministic description simultaneously of the positions and the momenta of the members of a mechanical system. It gives a deterministic description only for the probability distribution of those quantities.

In this, it departs radically from the previous theories which were from then

[1] In 1932, Nobel prize winner in physics “for the creation of quantum mechanics, the application of which has, inter alia, led to the discovery of the allotropic forms of hydrogen”.

[2] In 1954, shared with Walther Bothe, Nobel prize winner in physics “for his fundamental research in quantum mechanics, especially for his statistical interpretation of the wave-function”.

Fig. 8: From left to right: Pauli and Kronig.

on referred to as ‘classical’. The statistical nature of the theory was a major shock for physicists and is the reason why a few physicists still consider it to be an incomplete theory. Notably, Albert Einstein was among them.

The desperation of physicists, caused by the inapplicability of the ideas from classical physics to atomic systems, is very well depicted in a letter from 1925 of Wolfgang Pauli $1900 - 1958$, later a Nobel Prize winner in physics [1], to his assistant Ralph Kronig $1904 - 1995$:

> ‘Currently, Physics is again very muddled. For me at least, it is to complicated and I wished I would be a comic artist of the screen or similar and would never have heard anything from physics. But still I hope that Bohr will save us with a new idea.’

4.5 Quantum Electrodynamics

Quantum Electrodynamics is the result of the attempt to develop a Quantum Mechanics which is compatible with the Theory of Special Relativity.

[1] in 1945, ”for the discovery of the Exclusion Principle, also called the Pauli Principle”.

It describes the interaction of charged matter. In this theory, matter and the electrodynamic field are treated on the same footing, namely as objects that can act as particles or fields. *In classical physics both properties are incompatible*. In addition, it leads on the existence of antimatter that in collision with the corresponding matter annihilates to light. Also the opposite process is possible. As a consequence, matter and light can be considered as two manifestations of one field. Some of the most precise tests of Quantum Electrodynamics have been experiments dealing with the properties of subatomic particles known as muons. The magnetic moment of this type of particle has been shown to agree with the theory to nine significant digits. Agreement of such high accuracy makes Quantum Electrodynamics one of the most successful physical theories so far devised.

4.6 The Standard Model of Particle Physics

The Standard Model of Particle Physics is a generalization of Quantum Electrodynamics which also includes weak and strong nuclear forces that are in particular responsible for radioactive decay and the stability of atomic nuclei. It does not take into account the gravitational field. Until recently, it has proved highly successful in the description of experimental observations. However, experiments in 1998, (K2K-I) 2004 (K2K-II) and 2006 (MINOS) indicate that neutrinos have mass which is not taken into account in the standard model.

Also, one of the basic assumptions of particle physics in general is the ancient idea (Democritus, ca. $460 - 370$ BC) of the existence of 'atoms' [1], i.e., of particles that are 'fundamental' in the sense of not being composites of others. The history of particle physics does not seem to support this idea.

[1] The Greek word 'atomiki' means 'indivisibles'.

5 Conclusions

I hope, it has been made clear that natural sciences pose *no threat to faith because of the inherent limitations of their approach*. Abstracted world views pose a potential threat, but leave the firm ground of natural sciences and therefore constitute belief systems that cannot claim exactness.

That such abstractions are inherently flawed can also be read off from the development of the root of natural sciences, i.e., physics. Its development led to a sequence of theories which give the impression of insights into nature of increasing deepness and comprehensiveness. Still, each new theory negated fundamental aspects of its predecessor. It is not to be expected that this will change in future. This indicates that every physical theory contains some fundamentally false aspects which would be inherited by an abstracted world view.

In addition, it should also be taken into account that the majority of the creators of modern physics, in particular,

> Kepler, Galilei, Newton, Descartes, Laplace, Leibniz, Maxwell, Planck, Heisenberg and Jordan

were Christians that did not see any contradiction between their work and their faith. Finally, I see no better way to conclude this paper with the final words of Max Planck in his speech "Religion und Naturwissenschaft" [26] (Religion and Natural Sciences) from 1937:

Hin zu Gott!

which translates to

Towards God!

References

[1] Born M, Jordan P 1925, *Zur Quantenmechanik*, Zeitschrift für Physik, **34**, 858-888.

[2] Britannica Concise Encyclopedia 2006.

[3] Born M, Heisenberg W, Jordan P 1925, *Zur Quantenmechanik II*, Zeitschrift für Physik, **35**, 557-615.

[4] Borzeszkowski H-H, Wahsner R 1980, *Newton und Voltaire*, Berlin: Akademie Verlag.

[5] Chojecka E 1967, *Johann Kepler und die Kunst. Zum Verhältnis von Kunst und Naturwissenschaften in der Spätrenaissance*, Zeitschrift für Kunstgeschichte, **30**, 55-72.

[6] Cohen I B 1983, *The Newtonian revolution*, Cambridge: University Press.

[7] Copernicus N 1995, *On the revolutions of heavenly spheres*, New York: Prometheus Books.

[8] Dijksterhuis E J 1985, *The mechanization of the world picture*, Princeton: Princeton University Press.

[9] Einstein A 1905, *Zur Elekrodynamik bewegter Körper*, Annalen der Physik, **17**, 891-921.

[10] Einstein A 1915, *Die Feldgleichungen der Gravitation*, Sitzungsberichte der der Preussischen Akademie der Wissenschaften zu Berlin, 844-847.

[11] Einstein A 1916, *Die Grundlage der allgemeinen Relativitätstheorie*, Annalen der Physik, **49**, 769-822.

[12] Einstein A 2005, *Mein Weltbild*, Zürich: Europa Verlag.

[13] Galilei G, *Discoveries and Opinions of Galileo*, Translated with an introduction and notes by Stillman Drake, New York: Anchor Books.

[14] Galileo G 2002, *Dialogues concerning two new sciences*, Philadelphia: Running Press.

[15] Heisenberg W 1971, *Schritte über Grenzen*, München: Piper & Co. Verlag.

[16] Heisenberg W 1925, *Über quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen*, Zeitschrift für Physik, **33**, 879-893.

[17] Jordan P 1963, *Der Naturwissenschaftler vor der religiösen Frage*, Oldenburg: Gerald Stalling Verlag.

[18] Kepler J, Dyck W 1951, *Gesammelte Werke*, Vol. 15, p. 146. In a letter to Herwart von Hohenburg from 10th of April 1605.

[19] Kepler J 2002, *Harmonies of the world*, London: Running Press.

[20] Koestler A 1968, *The sleepwalkers*, London: Penguin Books.

[21] Laplace P S 1995, *A philosophical essay on probabilities*, New York: Dover Publications.

[22] Lewis C S 1994, *The Discarded Image: An Introduction to Medieval and Renaissance Literature*, Reprint edition, Cambridge: Cambridge University Press.

[23] Newton I 1999, *The Principia*, Berkeley: University of California Press.

[24] Margenau H, Varghese R A 1992, *Cosmos, Bios, Theos*, Chicago: Open Court Publishing.

[25] Maxwell J C 1891, *A Treatise on Electricity and Magnetism*, London: Clarendon Press.

[26] Planck M 1937, *Religion und Naturwissenschaft*, in: Planck M, *Wege zur physikalischen Erkenntnis*, 4th ed., Leipzig: Hirzel Verlag.

[27] Enz C P, v. Meyenn K (eds.), *Wolfgang Pauli - Wissenschaftlicher Briefwechsel*, Vol. 1, Letter 89, 215.

[28] Strong E W 1952, *Newton and God*, Journal of the History of Ideas, **13**, 147-167.

[29] Voltaire 1978, *Letters on England*, London: Penguin Books.